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Title Page

**The acute effects of integrated myofascial techniques on lumbar paraspinal
blood flow compared with kinesio taping: A pilot study.**

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ABSTRACT

Background:

Myofascial techniques and Kinesio Taping are therapeutic interventions used to treat low back pain. However, limited research has been conducted into the underlying physiological effects of these types of treatments.

Objectives

The purpose of this study was to compare the acute effects of integrated myofascial techniques (IMT) and Kinesio Tape (KT) on blood flow at the lumbar paraspinal musculature.

Methods

Forty-four healthy participants (18 male and 26 female) (age, $26 \pm \text{SD } 7$) volunteered for this study and were randomly assigned to one of three interventions, IMT, KT or a control group (Sham TENS). Paraspinal blood flow was measured at the L3 vertebral level, using Near Infrared Spectroscopy (NIRS), before and after a 30-minute treatment. Pain Pressure Threshold (PPT) was also measured before and after treatments.

Results

A one-way ANOVA indicated a significant difference between groups for O₂Hb [$F(2-41) = 41.6, P < 0.001$], HHb [$F(2-41) = 14.6, P < 0.001$] and tHb [$F(2-41) = 42.2, P < 0.001$]. Post hoc tests indicated that IMT was significantly greater, from the KT and the control treatments ($P < 0.001$), for changes in O₂Hb, HHb, and tHb. There were no significant differences for PPT [$F(2-41) = 2.69, p = 0.08$], between groups.

Conclusions

This study demonstrated that IMT increases peripheral blood flow at the paraspinal muscles in healthy participants compared to KT and sham TENS. The change in blood flow had no impact on pain perception in the asymptomatic population group.

INTRODUCTION

Lower Back Pain (LBP) is a multifactorial dysfunction with many possible causes and a variety of treatments (Richmond 2012). It has been estimated that LBP is a condition which affects over 70% of people in the developed world (Chou, 2010). It causes more disability globally than any other musculoskeletal condition (Hoy et al. 2014), and it is one of the most costly conditions in the UK (Maniadakis and Gray, 2000). It is estimated that 90% of LBP will resolve within 3 months but 10% will develop into chronic LBP (Andersson 1999). Impaired blood flow and greater fatigability of the paraspinal muscles have been identified as possible mechanisms associated with LBP (Mori et al. 2004). Previous studies have suggested that LBP subjects exhibit higher muscular loads, increased intramuscular hypoxia and a limited capacity for the paraspinal muscles to consume oxygen (Sakai et al. 2012; Kovacs et al. 2001). Decreases in blood flow to the lumbar paraspinal region have also been associated with detrimental adaptations to proprioception (Thomas and Segal, 2004) and lumbosacral position sense (Brumagne et al., 2013).

Two interventions that have been proposed to improve blood flow are massage therapy and kinesio taping (KT) (Mori et al. 2004; Hagen et al., 2015). The effects of massage on blood flow are equivocal and may be due to inconsistencies in the research such as small sample sizes, lack of control groups (Weerapong et al. 2005) and measurement limitations that make real time measurements of blood flow in massage problematic (Munk et al. 2012). However, these studies refer to more traditional forms of massage and did not use NIRS technology, which provides a non-invasive, dynamic measurement of blood flow to the muscle tissues (Munk et al. 2012)

Myofascial techniques are a form of manual therapy that involves focal soft tissue work to fascia and connective tissues and is widely employed to reduce pain and improve physiological functions (Ajimsha et al. 2014). Various methods and systems have been proposed including myofascial release (Barnes, 1997), connective tissue massage (Holey, 2000), fascial manipulation© (Picelli et al., 2011) and fascial release (Earls and Myers, 2010). For clinical purposes a variety of fascial techniques can be integrated to manipulate and stretch the myofascial or connective tissue layers to achieve various focussed therapeutic goals (Sherman et al., 2006). These include restoring optimal tissue length, reduce pain, improve tissue circulation and improve function (Ajimsha et al., 2014; Barnes, 1997; Celenay et al., 2016; Myers, 2009). It has been postulated that, following injury or a lack of movement, fascia can form adhesions and abnormal cross-links rendering the fascia less pliable and resistant to movement (Bouffard et al., 2007). It has also been proposed that myofascial techniques can influence the ground substance of the connective tissues and mechanoreceptors within fascia, contributing to changes in local fluid dynamics, reducing excessive muscle tension, capillary constriction, and improve local blood flow (Schleip, 2003). Although these studies were not specifically related to LBP it suggests that myofascial techniques may have a role to play in improving blood flow in LBP patients.

Kinesio taping is a popular intervention choice in the treatment of low back pain (Álvarez-Álvarez et al. 2014). It is proposed that the application of Kinesio taping to a stretched muscle creates convolutions to the skin (Kase and Wallis 2003). These convolutions are believed to lift the skin and underlying fascia, creating room for increased blood and lymphatic flow (Kase and Wallis, 2003), reducing pressure on subcutaneous nociceptors, and subsequently reducing pain (Parreira et al., 2014).

Studies on the effects of KT on blood flow are also limited and show conflicting results (Stedje et al. 2012; Williams et al., 2012), however, the ability to affect muscle endurance and improve fatigue has been identified and may be effective in the management of LBP (Hagen et al. 2015).

Currently, it is not known whether KT or myofascial techniques can improve blood flow, nor have these techniques been compared directly. Therefore, the aim of the present study is to determine whether KT or integrated myofascial techniques (IMT) have the potential to increase blood flow. The acute effects of KT and IMT were determined in a healthy population to determine the efficacy of both treatments compared with a sham treatment

METHODS

Participants

Participants were drawn from the student population at the University of Kent and the local area (table 1). An a priori analysis for sample size N was calculated using G*Power 3.1 (Faul et.al., 2007) as a function of the required power level set at 80% and a pre specified significance level of 0.05. An overall sample size of 42 was calculated. Participants were recruited using electronic mail, and posters located at the university campus. Subjects were excluded from this study if they were suffering from low back pain, diagnosed with serious infection in the preceding two weeks, previous severe back or leg injury, surgery on the back, spinal deformity, ankylosing spondylitis, rheumatoid arthritis; in any part of the body; any history of spinal fracture, a tumour in the back, an infection around the spine, any root compression or spinal disc damage, cancer, or any bleeding disorder. Other exclusion criteria included

currently taking warfarin or similar blood thinning medication, taking corticosteroid medication, e.g. Prednisolone, or high doses of inhaled steroids. The University of Kent's School of Sport and Exercise Sciences Research and Ethics Committee approved this study. All participants were asked to complete an informed consent form and pre-test questionnaire prior to any measurement or testing procedure. This was a pilot study using asymptomatic subjects. None of the participants were excluded under the exclusion criteria above. One subject was unable to attend due to personal reasons (see figure 3). All testing and data collection was conducted at the University of Kent's Sports Ready Clinic.

Insert table 1 here

Study design

The study was a parallel designed, non-cross over randomised control trial pilot study designed to compare IMT with Kinesio Tape as possible interventions for patients with LBP. Participants were randomly assigned into a 30-minute treatment of either KT, IMT and sham Transcutaneous Electrical Nerve Stimulation (TENS) control group. Randomisation was achieved through simple allocation using a random allocation. Recruitment of subjects was cumulative. On arrival, subjects were asked to choose one of three envelopes, which concealed the allocation group. Subjects were allocated by drawing the next consecutive envelope. A member of the team; not involved in administering the interventions; conducted randomisation and assignment of subjects. Subjects were then allocated to that intervention. The independent variable consisted of the treatment condition (IMT, KT and a sham TENS control condition). The dependent variables were the change in peripheral

blood flow and pain pressure threshold values at the lumbar paraspinal region. Oxygenated haemoglobin (O_2Hb) was determined by the relative concentration changes in oxygenated haemoglobin and myoglobin. De-oxygenated haemoglobin (HHb) was determined by the relative concentration changes in deoxygenated haemoglobin and myoglobin. Total haemoglobin (tHb) was determined by the sum of O_2Hb and HHb and was used to provide the total change in blood volume. Tissue oxygen saturation (TSi); an absolute measure of oxygen saturation within the tissues; was also measured at the lumbar paraspinal region.

Measurements

Blood flow measurements

Blood flow and oxygenation measurements were collected using Near Infrared Spectroscopy (NIRS) technique (see figure 1). The NIRS data was collected Bi-laterally at the lumbar para-spinal region (Oxysoft mk III Near Infrared Spectroscopy System, Artinis Medical Systems[®]Arnhem). Before each testing session, the NIRS instrumentation was calibrated according to manufacturer's specifications. Sampling locations for the spectrophotometers were bi-laterally at the level of L3, 3 cm from the spinous process (Ning et al., 2011). The area was prepared by removing any hair and cleaned with a sterile wipe. The spectrophotometers were then applied to the skin using adhesive tape. A black cloth was placed loosely over the area, completely covering the NIRS sensors to block any ambient light from reaching the sensors. Baseline readings of light reflected from the underlying tissues were recorded. Samples were recorded for two minutes before and after each treatment at 20 samples / second, with the spectrophotometers removed during each treatment. Following each treatment, the sensor locations were re-cleaned with a sterile wipe

and the spectrophotometers were returned to the same pre-treatment sensor locations. The NIRS protocol recorded Tsi, O2Hb, HHb and tHb. NIRS raw data for the 2-minute period before and after interventions were exported to excel for further analysis. Tsi, O2Hb, HHb and tHb measurements were averaged over the 2-minute period. Left and right side data was then averaged to prior to further statistical analysis. All testing was conducted in the same room in which the intervention was applied, minimising the effect of movement on the test results.

Insert figure 1 here

Skinfold and pain pressure threshold measurements

A skinfold measurement of adipose tissue was obtained on all participants on the right side three centimetres from the L3 vertebra (Harpender Callipers®, Batty International, Sussex, and UK). Perceptions of pain pressure were taken before and after the treatment on both the left and right sides three centimetres from the L3 vertebra. (Baseline® Algorimeter, Wagner Instruments, Greenwich, US).

Treatment Protocols

Integrated myofascial techniques (IMT)

A trained massage therapist with 3 years of practical experience conducted the IMT treatments. The rationale behind the treatment choice was to integrate a number of myofascial techniques that could be typically used within a clinical setting for specific clinical purposes. For this reason a combination of commonly used techniques including Myofascial Release (MFR) (Barnes, 1997), fascial release techniques (Earls and Myers, 2010; Myers, 2009), and connective tissue skin rolling were

chosen. In this case the techniques were designed to focus specifically on the fascia and connective tissue structures of the lower back in order to monitor their effects on peripheral blood flow to that region of the body. The therapist provided one treatment designed specifically to identify and address musculoskeletal contributors to the lower back region using integrated myofascial techniques (see table 2). Each IMT treatment lasted for 30 mins.

Kinesio taping condition

A therapist trained in the application of this taping technique conducted the KT treatment. The therapist had 2 years' experience of using Kinesio Tape in practice. The KT method was a standardised from a technique by Kase et al., (2003). Two "I"-Shaped Kinesio Rock Tape® elastic bandage was attached directly to the patients' skin over the erector spinae parallel to the spinous processes of the lumbar vertebrae. A standardised reference point from the posterior superior iliac spine (PSIS) to the thoracic eight vertebrae (T8) was implemented according to the Kenzo Kase's Kinesio Taping Method Manual, (1996). The skin was cleaned and shaved (if required) in preparation for the tape. The tape was anchored (approximately five centimetres) at the base of the KT strip to the posterior superior iliac spine with no tension. The therapist removed the paper backing from the base of the 'I' strip leaving the remainder of the paper backing on the "I" strip. Care was taken not to handle the adhesive side of the tape. The clients were asked to flex the lumbar spine by leaning forward from the hip therefore placing the erector spinae muscles in a lengthened position. Two vertical 'I' strips were equally applied upwards on either side of the spine over the skin area with a light tension of ten to fifteen percent stretch. The application was completed when the proximal base of the KT was placed approximately five centimetres above the vertebra T8 with no tension. The

therapist activated the adhesive glue by rubbing the tape onto the skin using the paper backing from the tape. The KT treatment lasted for 30 minutes before the tape was removed for retesting.

Sham TENS

The TENS treatment was conducted by a therapist trained in the use of electrotherapy. The therapist had 2 years' experience of using electrotherapy in practice. Participants were required to lay prone on a treatment plinth. The area for treatment was cleaned and shaved (if required). Two sterile electrodes were placed bi-laterally at the level of L3, three centimetres from the spinous process. The Intellect® Mobile Combo Electrotherapy and ultrasound machine (Chattanooga Medical Inc, US) was programmed for a 30 minute treatment. Following electrode placement, the participant lay prone while no electrotherapy was performed. In order to blind participants to the SHAM condition, the machine was placed out of sight so that participants could not see the display (Jaffer, Daly, Yadav, Marshall & Graeme, 1986). The treatment lasted for 30 minutes before the electrodes were removed for retesting.

Insert Figure 2 here

Statistical Analysis

Statistical analyses were performed in SPSS (IBM SPSS for Windows, version 21.0. Armonk, NY: IBM Corp). The normality assumption was assessed using Shapiro-Wilk tests. Skinfold thickness and BMI values were measured to determine any differences in body composition between groups. The dependent variables of Tsi, O2Hb, HHb, tHb were obtained by averaging the values over the two-minute measurement period. The dependent variables of Tsi, O2Hb, HHb, tHb, and ratings

of pain pressure threshold were analysed using a one-way ANOVA comparing the change in values from pre to post measurements between each group. The independent variables were the treatment groups (IMT, KT and sham TENS). Statistical significance level was set at $\alpha < 0.05$. Post hoc analysis was used to identify pairwise differences in blood flow and PPT between each group. Estimation of effect size from the pre-test, post-test-control design was calculated according to (Morris, 2008).

$$d = \frac{(M_{\text{post}, T} - M_{\text{pre}, T}) - (M_{\text{post}, c} - M_{\text{pre}, c})}{\text{Pooled SD}_{\text{pre}}}$$

Where M_{pre} and M_{post} T represent the pre-test and post-test means for the treatment group; M_{pre} and M_{post} c represent the pre-test and post-test means for the control group and SD_{pre} represents the pooled standard deviation from the treatment and control groups. Effect sizes were considered as small (0.2), moderate (0.5) and large (0.8).

RESULTS

Figure 3 outlines the participant flow including, enrolment, participant allocation, randomisation and analysis. One participant was unable to take part in the study due to personal reasons.

Insert Figure 3 here

Tissue Oxygenation and blood flow

Table 3 represents the mean and SD values for the change in tissue oxygenation and blood flow between groups. Results of a one-way ANOVA revealed statistically significant differences between groups for the change in O2Hb [$F_{(2-41)} = 41.6$, $P = <0.001$], HHb [$F_{(2-41)} = 14.6$, $P = <0.001$] and tHb [$F_{(2-41)} = 42.2$, $P = <0.001$]. Post hoc analysis revealed that significantly greater changes in O2Hb for the IMT group compared to the KT group and control ($p < 0.001$). There was no significant difference in the change in O2Hb between the KT group and control ($p = 0.789$). Post hoc tests also revealed significantly greater changes in HHb and tHb for the IMT group compared to the KT group and the control group ($p = <0.001$). There was no significant difference between changes in HHb ($p = 0.881$) and tHb ($p = 0.769$) between the KT and control group.

Insert Figure 4 here

Insert Table 2 here

Body Fat and Body Mass Index

Descriptive data analysis revealed that skinfold thicknesses were not normally distributed, however BMI was. A one-way ANOVA revealed no significant difference for BMI [$F_{(2-41)} = .049$ $P = 0.953$] between groups. A Kruskal-Wallis Test revealed no difference in skinfold measurement between groups, [$H_{(2)} = 4.3$, $p = 0.59$].

Pain Pressure Threshold

A one-way ANOVA revealed no significant difference between groups for PPT changes, [$F_{(2-41)} = 2.69$, $p = 0.80$].

DISCUSSION

The results of this study indicate that, in healthy participants, a 30minute treatment using IMT techniques produced significantly greater increases in peripheral blood volume at the lumbar paraspinal region compared to KT and a control group. However, changes in PPT and Tsi did not differ between groups.

The present study is the first of its kind to compare changes in peripheral blood volume following manual IMT therapy and KT using NIRS at the paraspinal region. Previous studies into massage and blood flow have been largely inconclusive due to the inconsistencies surrounding Xenon wash-out technique and the inability of Pulsed Doppler ultrasound to measure microcirculation within the muscle (Munk et al. 2012; Weerapong et al. 2005). Previous studies have assessed the effects of massage on changes in blood flow using Doppler techniques (Taspinar et al. 2013; Hinds et al. 2004; Shoemaker et al. 1997), Dynamic Infrared Thermography (Sefton

et al. 2010) and NIRS techniques (Mori et al. 2004; Durkin et al. 2006). Previous studies have both supported (Mori et al. 2004; Sefton et al. 2010); and not supported (Shoemaker et al. 1997) the premise that massage has the potential to improve blood flow and oxygenation. The current study utilised NIRS technique to measure blood volume. NIRS is a non-invasive technique that provides dynamic measures of blood volume and tissue oxygenation and has been widely used to monitor these parameters within muscle (Durkin et al., 2006; Ferrari and Mottola, 2004; Munk et al., 2012; Sakai et al., 2012).

The major effects of IMT found in this study were markedly higher levels of O₂Hb, HHb and tHb. As NIRS provides continuous monitoring of both oxygenated and deoxygenated haemoglobin and myoglobin and the sum of O₂Hb and HHb are considered to represent the change in blood volume (Olivier et al. 2013), It is reasonable to assume that the results of this study indicate a change in total blood volume at the lumbar paraspinal region following IMT. One possible explanation for the increase in blood volume may be due to the restoration of normal tissue structure and function following IMT. It has been argued that fascial restrictions within the connective tissue network may result in stress on muscle tissues and pain sensitive structures that are enveloped, supported or divided by these connective tissue (Ajimsha et al. 2014). It has been suggested that these restrictions may result from alterations in ground substance (Hanten & Chandler 1994) and the presence of adhesions due to injury, stress and repetitive use (LeBauer et al. 2008). It is proposed that IMT techniques are able to alter the ground substance (Ercole et al. 2010), and muscle architecture through thixotrophy and tensegrity principles (Arroyo-Morales, Olea, Martínez, et al. 2008), restoring extensibility between fascial layers,

relieving pressure on structures such as nerves and blood vessels and, therefore, restoring normal neural and vascular dynamics to the region.

Another possible theory is that IMT techniques may lead to an increase in intramuscular blood flow through stimulation of the autonomic nervous system. It is reported that the lumbar paraspinal muscles in a state of contracture of around 20-30% of MVC result in a significant decrease in oxygenation (Jensen et al., 1999). IMT techniques may have stimulated mechanoreceptors within the fascial network resulting in an autonomic nervous system mediated vasodilatation and a reduction in muscle tension and tonus (Schleip 2003). Reducing excessive muscular tension may, therefore, reduce capillary constriction and improve blood flow. It is possible that the sustained pressure and traction associated with IMT is able to stimulate type III and IV mechanoreceptors, triggering a predominantly parasympathetic response (Arroyo-Morales, Olea, Martinez, et al. 2008). In contrast, the findings of this study did not support the use of KT to improve blood flow at the paraspinal region.

Although it is theorised that KT creates convolutions in the skin that could increase circulation and lymphatic flow, our data did not support this theory and is in agreement with previous studies (Stedje et al. 2012). One possible reason for this may have been that the length of time that the KT tape was applied within this study may not have been optimal for this type of intervention. It has been proposed that KT tape should be applied for 3-5 days (Kase K, Wallis J 2003).

Tissue saturation was not significantly altered following any of the treatments. The Tsi value can be seen as a measure of dynamic balance between oxygen delivery and use (Janssens et al., 2013). This result may be explained by the relatively sedentary nature of the interventions, as the paraspinal muscles were not active enough to alter the balance between oxygen demand and oxygen use.

The results of this study indicated PPT did not alter after IMT and there was no difference between groups. This result was at odds with a number of other studies that demonstrated reductions in pain following the use of IMT (Castro-Sánchez et al. 2011; LeBauer et al. 2008; Ajimsha et al. 2014). Indeed, the study by Castro-Sánchez et.al. (2011), identified a significant fall in the number of painful spots associated with Fibromyalgia including lower cervicals, left trapezius muscle, the second ribs and gluteal muscles. While one of the proposed benefits of IMT is to reduce pain, the population group used for this study was a healthy a-symptomatic one. Previous investigations into the effects of IMT on healthy populations have also found that pain was not altered following treatment (Arroyo-Morales, Olea, Martínez, et al. 2008),

This was a pilot study with several limitations and it is, therefore, important to point out that the conclusions of this study are limited. The myofascial intervention within this study utilised an integrative approach that, although may be applied in a clinical setting, does not allow us to attribute the results of this study with any single myofascial technique. Indeed the acute changes in blood flow identified in this study could be attributed to any one or all of the techniques outlined. Furthermore, this study investigated the effects of IMT on asymptomatic subjects; therefore any effects identified in this study could not be used to imply clinical significance to the LBP population. Future studies should attempt to make a comparison between different myofascial techniques and or with different types of massage methods using symptomatic subject groups. Future studies should also look to control participant's activities before testing were not controlled. The depth, pressure and speed of IMT techniques could not be fully standardised, however, in this study; in order to standardise these variables as much as possible; the same therapist was used to

conduct all the IMT treatments. The current study only identified immediate changes in blood volume. To assess the effects of IMT in the long term, future studies should explore the blood volume changes associated with repeated treatments and or the duration of the treatment effects following myofascial techniques.

In conclusion this study demonstrated that the application of 30 minutes of integrated myofascial techniques increases peripheral blood volume at the paraspinal region, in healthy participants, compared to kinesiology tape and sham transcutaneous electrical nerve stimulation. The changes in peripheral blood volume had no impact on pain perception in this asymptomatic population. Therefore, integrated myofascial techniques may have a possible role in the management of LBP, through improved O₂ delivery and blood volume increases to the paraspinal muscles.

Conflict of interest

There were no identified conflicts of interest.

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TABLES

Table 1–Participants characteristics by group (mean \pm SD)

Group	N (male/female)	Age (yrs)	Height (cms)	Weight (kg)	BMI
IMT	15(M=8,F=7)	28.3 (7.6)	172 (11.5)	70.6 (10.3)	24.0 (3.7)
KT	15(m=6, F=9)	25.4 (8.8)	170 (7.6)	70.2 (13.3)	24.3 (3.6)
Control	14(m=4, F=10)	23.5 (6.6)	170 (7.6)	67.1 (10.4)	23.9 (3.2)

Table 2–Integrated myofascial techniques treatment description.

Technique	Description	Repetitions/ duration
Prone position:	Compressions and vibrations applied through a towel. Myofascial release (MFR) cross hands technique, applied bi-laterally, to the spine at the lumbar region.	90 seconds second each side.
	Fascial release, longitudinal myofascial stripping applied bi-laterally with the knuckles, to the erectus spinae from approximately C7 to S1/2.	Ten repetitions.
	Connective tissue manipulation, skin rolling over the thoraco-lumbar fascia region from the sacrum, in a cephalad direction, through to T12.	Six repetitions each side

	<p>Fascial release, transverse myofascial stripping applied bi-laterally, with the fingers from a medial to lateral direction (from L5 to the mid thoracic region).</p> <p>Transverse myofascial stripping across the gluteal muscles in a medial to lateral direction from approximately L5 to S2.</p>	<p>Three repetitions each side.</p> <p>Three repetitions each side.</p>
Side lying	MFR cross hands to Quadratus Lumborum (QL) region between the iliac crest and T12.	90 seconds each side.
	Fascial release, myofascial stripping and active lengthening to the latissimus dorsi and QL, in a caudal direction, from T7 to the iliac crest using knuckles and or forearms.	Six repetitions each side
	Myofascial stripping and active lengthening to the lumbar erector spinae, in a caudad direction, from T12 to S1 using knuckles and or forearms.	Four repetition each side.
	Soft Tissue Release to the QL muscle.	Three repetitions each side
Seated	Fascial release, myofascial stripping and active lengthening from C7 to S1/2 region, using knuckles and or elbows with active forward flexion performed by the participant.	8 to 10 repetitions each side.

Table 3 - Mean and SD values for the change in blood flow variables for each group, results of the comparison between groups for Oxygenated haemoglobin (O₂Hb), De-oxygenated haemoglobin (HHb), Total haemoglobin (tHb), Tissue oxygen saturation (TSi) and effect sizes.

Group	IMT	KT	Control	IMT vs KT			IMT vs control			KT vs Control		
				Difference (95%CI)	P- value	Effect size	Difference (95%CI)	P- value	Effect size	Difference (95%CI)	P- value	Effect size
Change in O₂Hb (Mean ±SD)	22.34 (9.52)	1.87 (3.66)	1.16 (7.10)	20.46 (15.17 to 25.76)	< .001	1.73	21.18 (15.79 to 26.57)	< .001	0.85	0.717 (-4.67 to 6.11)	.799	0.03
Change in HHb (Mean ±SD)	3.42 (3.30)	-1.02 (1.62)	-1.25 (2.75)	4.44 (2.48 to 6.39)	< .001	0.39	4.67 (6.66 to 2.68)	< .001	0.19	0.24 (-1.75 to 2.22)	.811	0.003
Change in tHB (Mean ±SD)	25.76 (10.88)	0.86 (4.13)	-0.09 (9.60)	24.9 (18.49 to 31.31)	< .001	2.14	25.85 (19.33 to 32.37)	< .001	1.05	0.954 (-5.57 to 7.47)	.769	0.03
Change in Tsi (Mean ±SD)	2.81 (7.01)	0.31 (8.61)	1.32 (9.23)	2.50 (-3.6 to 8.65)	.416	0.28	1.50 (-4.76 to 7.75)	.632	0.07	-1.01 (-7.26 to 5.25)	.747	-0.07

ILLUSTRATIONS

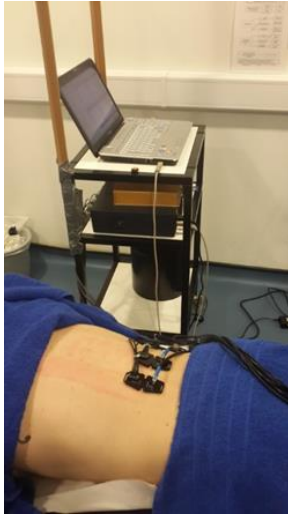


Figure 1 – NIRS placement (black cloth removed to highlight spectrophotometer positions)



Figure 2 - Sham TENS

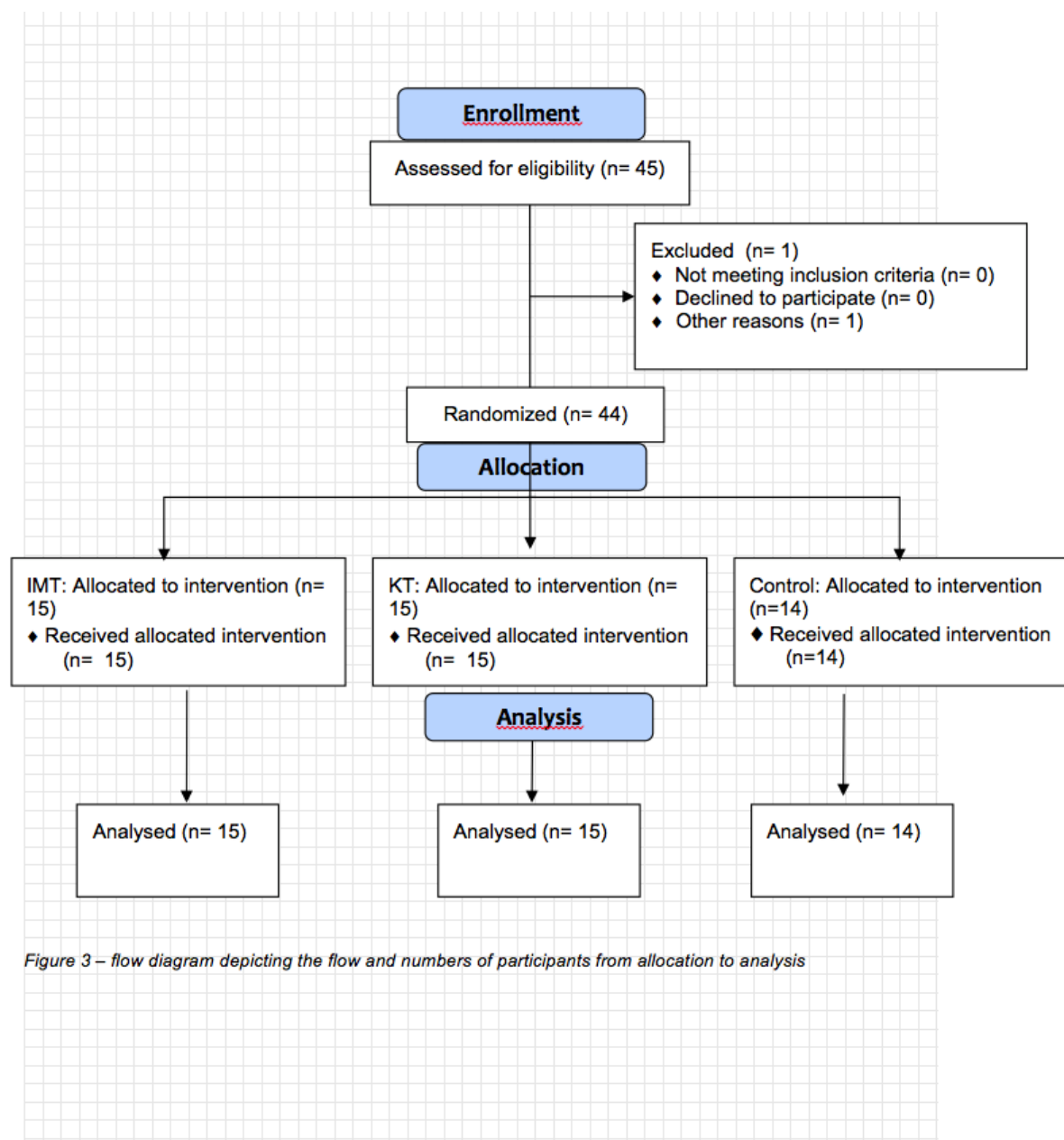


Figure 3 – flow diagram depicting the flow and numbers of participants from allocation to analysis

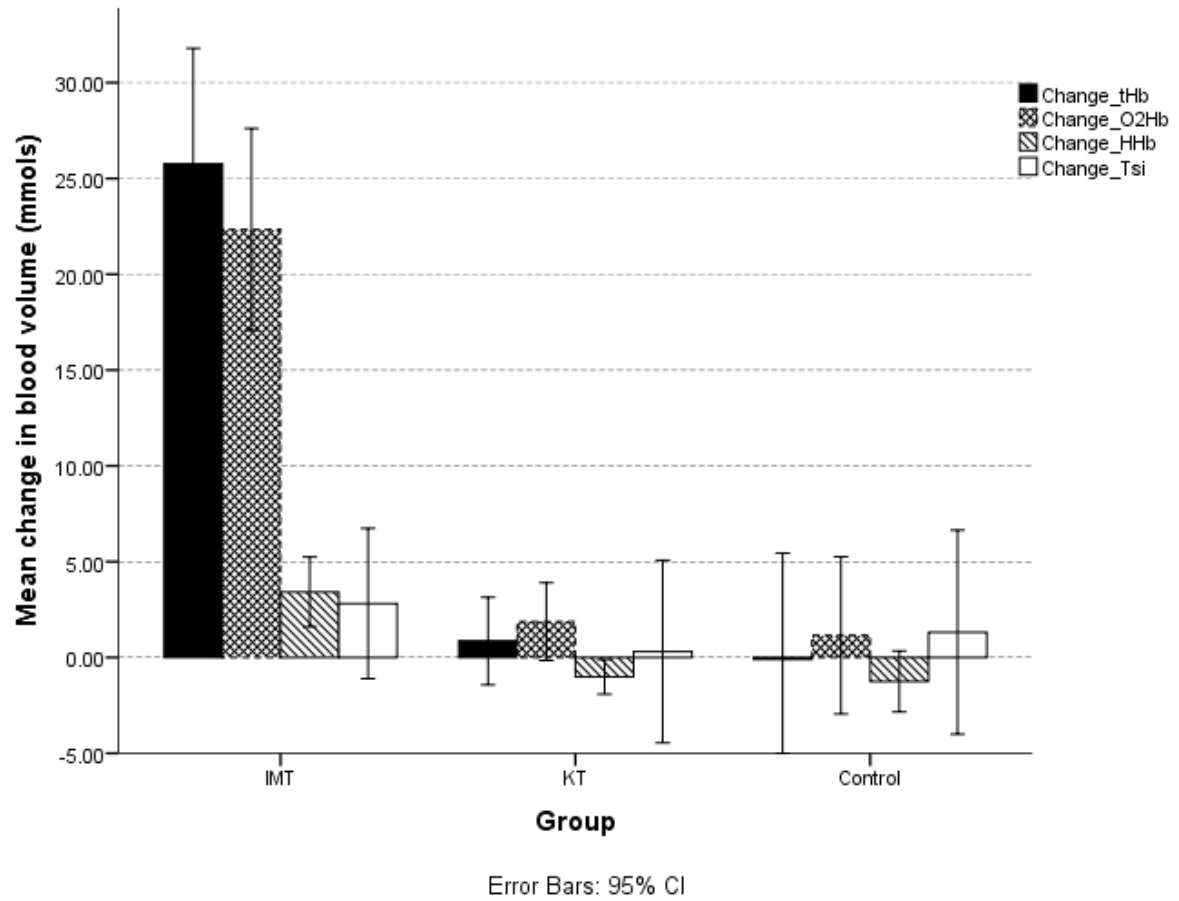


Figure 4 - Comparison of the change in blood volume variables between each group for total haemoglobin (tHb), dark bar; oxyhemoglobin (2Hb), chequered bar; deoxyhemoglobin (HHb), lined bar; and tissue saturation (Tsi) clear bar. (IMT = Integrated myofascial techniques KT = Kinesio Tape)

